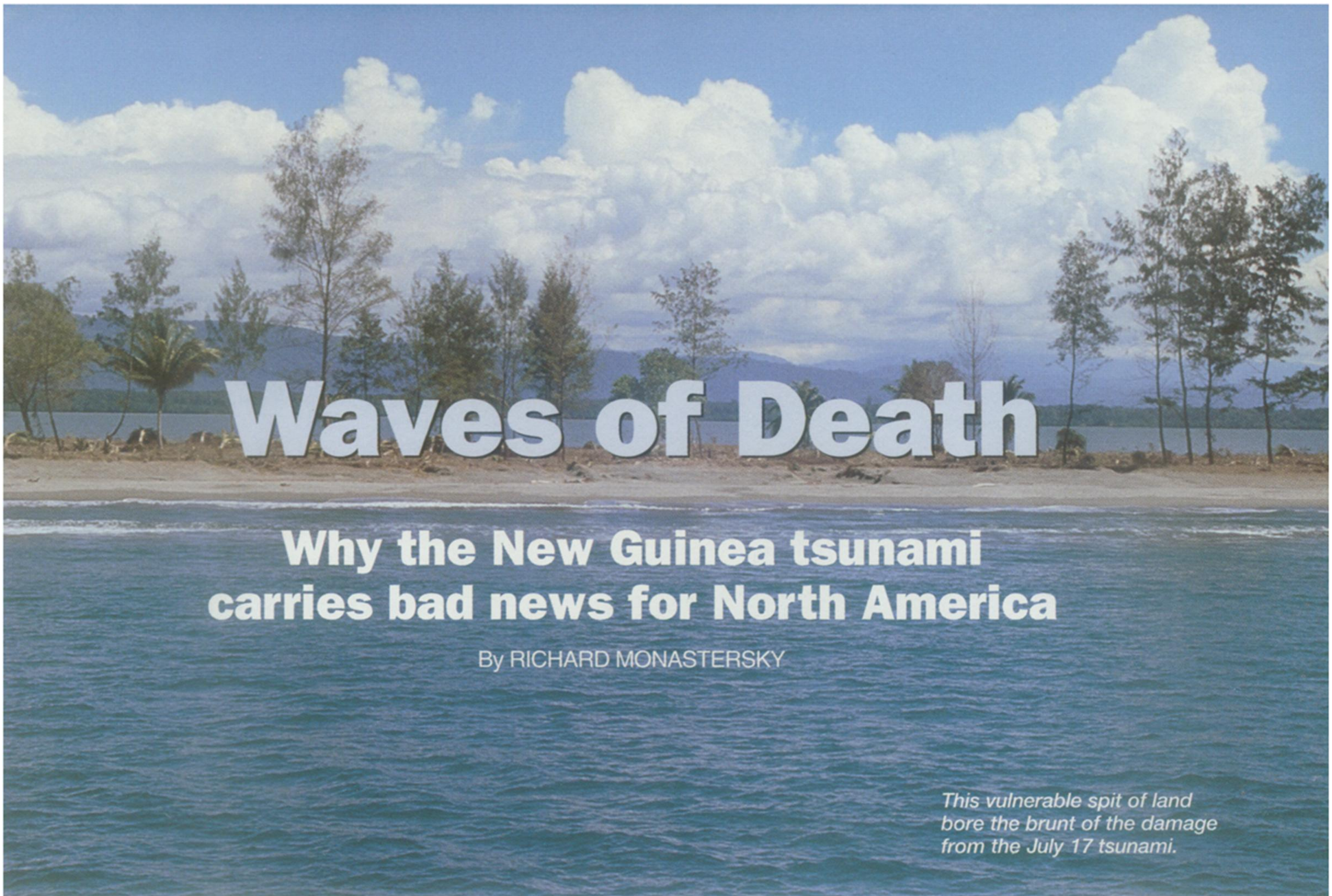
Waves of Death

Why the New Guinea tsunami carries bad news for North America

By RICHARD MONASTERSKY



This vulnerable spit of land bore the brunt of the damage from the July 17 tsunami.

Synolakis

When a devastating tsunami hits anywhere in the world, Costas Synolakis gets on the phone and starts arranging flights to the afflicted region. A hydrodynamic engineer, Synolakis has specialized in studying these giant sea waves, and nature has provided plenty for him to study in recent years. Between 1992 and 1997, Pacific earthquakes spawned nine tsunamis that claimed more than 1,800 lives. Yet these events didn't prepare him for the scale of the disaster in Papua New Guinea, where three mountainous waves pounded the northern coastline on July 17 and carried away at least 2,500 people.

"We were in a state of shock," says Synolakis, a researcher at the University of Southern California in Los Angeles and co-leader of a science team that visited Papua New Guinea in early August. "It was really something we had not seen before. It was sort of a new threshold in terms of what a wave can do."

Debris hanging from the tops of palm trees indicated that the waves reached heights of 14 meters, taller than a four-story building and more than twice the estimate reported by news agencies immediately after the catastrophe. In surveys of past disasters, Synolakis and his team had never before witnessed evidence of so much water flowing over a shoreline. "This is about double the worst overland flow that we had seen before," he says.

All this from an otherwise ordinary earthquake. The jolt that preceded the tsunami measured 7.1 on the moment magnitude scale, meaning it was a strong but fairly common quake. Tremors of at least this size strike somewhere on the globe about every 3 weeks. The United States has suffered three in the past 7 years.

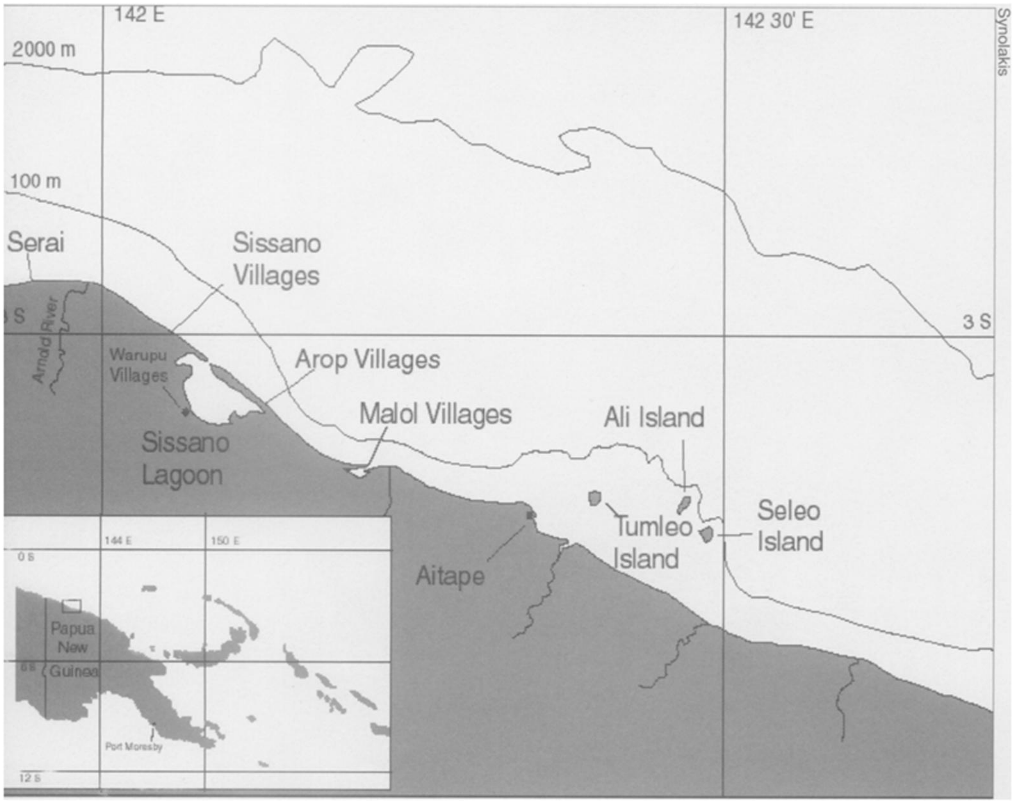
During their survey, Synolakis and his colleagues grew convinced of something they had suspected even before reaching Papua New Guinea. "Once we were there, we realized the earthquake itself could not have generated such a large wave." Their favored hypothesis now is that the earthquake triggered an underwater landslide that in turn generated the giant waves—a possibility that raises disturbing questions about the tsunami hazard elsewhere.

The coastline that stretches from California to the Pacific Northwest and southern Alaska has many similarities to the shores of Papua New Guinea, say tsunami researchers. The west coast of North America is laced with small coastal faults capable of producing moderate quakes and underwater slides in the steep-walled canyons offshore. "These [small faults] haven't been taken seriously as tsunami-generating sources before. We have to take a much closer look now," says Synolakis.

Of all natural disasters, tsunamis may rank as the most poorly understood by the general public. Media reports often describe them as tidal waves, although they bear no relation to tides. They are often portrayed as simply scaled-up versions of a breaking wave, similar to the famous painting by the Japanese artist Hokusai that appears on almost all tsunami web sites. But the truth lies far from that image.

Survivors of the Papua New Guinea disaster describe the tsunami as a wall of water barreling toward shore, according to the researchers. Unlike a normal wave with its prominent crest, the tsunami was more like a plateau of water, averaging 10 m high and extending 4 to 5 kilometers from front to back, says Synolakis. The largest wave swept over the shore at speeds of up to 20 km per hour for more than a minute, before draining away in preparation for the next. Imagine a mountain of water, appearing out of nowhere and plowing across the beach as if surging from a collapsed dam.

In their preliminary report to the National Science Foundation, which funded their postdisaster survey, Synolakis and his team say that the first of the three large waves arrived 5 to 10 minutes after the initial earthquake, with the others following several minutes later. The



The tsunami hit hardest in the villages of Arop and Warupu, and it claimed lives in the Malol villages.

tsunami struck an extremely limited region extending over only 20 km of coastline, unlike other recent tsunamis that spread devastation over hundreds of kilometers.

The waves happened to hit a particularly vulnerable section of the north coast, where a narrow strip of land separates the ocean from a brackish body of water called Sissano Lagoon. The lagoon itself formed during a tsunami in 1907, providing a warning that went unheeded.

With Sissano Lagoon blocking the route inland, the families of fishermen living on the sand bar had no way to escape the waves. The water washed away all evidence of the houses on this 300-meter-wide coastal strip, except for some bent 2-by-4 stilts that people had used to raise their homes off the sand.

Evidence collected along the coast confirms the initial seismological reports of the quake's moderate size, says team member Emile A. Okal, a seismologist with Northwestern University in Evanston, Ill. People who lived only 15 km from the most devastated area told the investigators that the shaking was not particularly intense in their village. "There were no houses destroyed by the earthquake. There were very few objects thrown down," says Okal.

Seismologists have noted that the earthquake was of slightly longer duration than typical shocks (SN: 8/1/98, p. 69), but this factor would not account for the large size of the tsunami, says Okal. Instead, investigators have had to search for other factors.

During its survey of the coastline, the team discovered a cliff with evidence of a fresh avalanche, which local residents attributed to the quake. Okal and his colleagues speculate that a similar, but much larger, slide happened underwater. The seafloor off the north coast plunges steeply into a submarine trench, and the sediments piled on this slope may easily slump downhill when shaken.

That would fit with the distribution of damage along the shore. "It is known that slumps can create extremely devastating tsunamis and extremely localized ones," says Okal.

There may have been a second factor adding to the instability of the slope, suggest the researchers. Sediments along the margin of continents often contain a frozen substance called methane hydrate, which can form slick surfaces buried beneath the seafloor. "Nobody knows what happens if gas hydrates get shaken by earthquakes," says Okal.

In other locations—off the coast of Norway and the southeastern United States—oceanographers have found scars of slumps that originated in regions replete with methane hydrate deposits (SN: 11/9/96, p. 298). If similar deposits exist along the coast of Papua New Guinea, they could have helped the sediments slip downslope after the initial earthquake, the researchers suggest.

At present, Okal calls the case for slumping circumstantial. To test the hypothesis, the scientists would need an oceanographic ship to scan the seafloor with sonar, looking for direct evidence of large, fresh slides. U.S. officials say that they are trying to obtain funds for such a survey, but so far none have surfaced.

The seafloor off Papua New Guinea reminds some researchers of other areas notorious in the tsunami field. In 1992, a strong and extremely slow earthquake off the coast of Nicaragua sparked a massive tsunami that killed 170 people. A seafloor survey conducted afterward showed scars from slides in a region known to be rich with methane hydrate, says Eddie Bernard, who is director of the Pacific Marine Environmental Laboratory in Seattle and coordinates the National Tsunami Hazard Mitigation Program.

Although scientists have known that subsea landslides can cause trouble, this issue has received scant attention in tsunami research. The Papua New Guinea disaster may provide a stark lesson on the dangers of slumping. "I think what this has done to the U.S. program is given it more emphasis to examine the slump-generated tsunami problem," says Bernard.

For decades, the United States has been playing catch-up with tsunamis, taking protective steps only in the wake of a disaster. In 1946, an earthquake in the Aleutian Islands set off a tsunami that crossed the Pacific and killed 159 people in Hawaii. In response, the National Oceanic and Atmospheric Administration (NOAA) opened a tsunami warning center in Hawaii.

In 1964, a giant Alaskan earthquake spawned a tsunami that took 111 lives in Alaska, California, and Oregon. Following that tragedy, NOAA established a second tsunami center in Alaska.

These U.S. installations have focused on providing warnings of tsunamis that are triggered by massive earthquakes and then cross the ocean to threaten far-off coasts. For years, these so-called distant tsunamis were seen as the biggest threat to the U.S. shores, says Synolakis.

In the mid-1980s, however, geologists working in the Pacific Northwest started discovering evidence of a home-grown hazard. Bays and wetlands along the coast of Washington and Oregon preserve signs of monstrous tsunamis generated by a giant offshore fault called the Cascadia subduction zone. This structure roared to life most recently in 1700, drowning large sections of the Pacific Northwest coast with a tsunami that also crashed into the coast of Japan, where it was recorded in official documents (SN: 4/8/95, p. 223).

As the Cascadia evidence accumulated in the 1990s, the Pacific rim suffered a string of devastating tsunamis, all generated by strong earthquakes relatively near to shore. The combination forced U.S. researchers to start looking in their own backyards.

Now, they must also worry about

smaller threats. "The main lesson [from Papua New Guinea] is that small, local faults have a much greater potential for tsunami generation than we had thought earlier," says Synolakis.

Angie Karel

Tsunami warning signs, like this one in Oregon, are going up along the coastline of the Pacific Northwest. If a giant earthquake strikes the region, as happened in 1700, enormous waves could batter the shores for 8 hours.

"This is something we're really worried about in California," he adds. Coastal regions such as Santa Barbara and Palos Verdes, near Los Angeles, face the threat of magnitude 7 quakes from small faults that run underwater, a situation reminiscent of Papua New Guinea.

Adding to the similarities, the seafloor off the coast of southern California drops into steep submarine canyons that are prone to landslides, says Bernard. Indeed, he notes that a highly localized tsunami struck Santa Barbara after an earthquake there in 1812. Although records from that time are sparse, written accounts report that the waves flooded a Spanish mission located 15 feet above sea level.

Okal draws parallels between Papua New Guinea and the Strait of Georgia, which runs between Vancouver Island and the mainland. The Fraser River has built up a large deposit of sediments in the strait that could slump in an earthquake. "We should target areas where sediments are piling up quickly and could be unstable," he says.

The Papua New Guinea disaster comes as the United States is waging an unprecedented campaign to reduce the hazard of tsunamis. The federal government in 1996 teamed up with Hawaii, Alaska, California, Oregon, and Washington to launch the "first systematic attempt to focus on the tsunami problem," says NOAA's Frank González who sits on the steering group of the mitigation program.

The team has taken a three-pronged approach. First, researchers such as Synolakis are using computer models to produce inundation maps showing credible worst-case scenarios.

Second, local officials and police use these maps as part of a public education process aimed at teaching communities what to do in case of a tsunami.

Finally, the program seeks to develop sensors that would sit on the ocean floor and transmit warnings of an approaching tsunami. Located in the deep reaches of the ocean, such instruments would help primarily in cases of distant tsunamis, in which officials often have hours to prepare for the waves' arrival.

In the case of earthquakes close to a coastline, the tsunami hits the shore in only a few minutes and the deep-ocean warning system offers no aid. The mitigation program is therefore teaching local residents to rely on warning signs provided by nature. The message is fairly simple, says González: "If you can see the ocean and you feel the earthquake, run like hell away from the water."

Even just 2 minutes of warning gives people enough time to flee a few hundred meters inland, which can carry them beyond the strongest pulse of the tsunami. "It's irrefutable that you can save lives by this kind of training," says González.

More than a thousand residents of Okushiri, Japan, can testify to that statement. In 1993, a powerful earthquake, magnitude 7.8, hit the coast of this island at 10:00 p.m. Within about 6 minutes, the tsunami crashed into shore and killed 200 people. A total of 1,200 people escaped the waves, however, when they ran inland after feeling the shaking, says Bernard.

In its educational literature, NOAA advises coastal residents to evacuate if the shaking is strong enough that people must hold onto something to keep from falling. Yet the tremors in Papua New Guinea never grew that intense, according to estimates made by Okal and his colleagues.

Interviews with witnesses have provided some other warning signs that coastal residents can look for. People in Papua New Guinea saw the ocean withdraw before the first wave hit, an observation consistent with reports from several other recent tsunamis. Moreover, witnesses said they could hear the wave coming.

"If you hear a large roar, especially at night when you can't see the ocean, that's an indication a tsunami is approaching. You don't want to wait to see this thing. You want to be moving," says Bernard. □